Warmup: *Read the section entitled "**Light as a Wave**" on pages **116/117** (to above the figures), then answer these questions.*

2.2: The Forensic Analysis of Glass

SFS 2: Use various scientific techniques to analyze physical and trace evidence

b. Analyze the morphology and types of hair, fibers, soil and glass

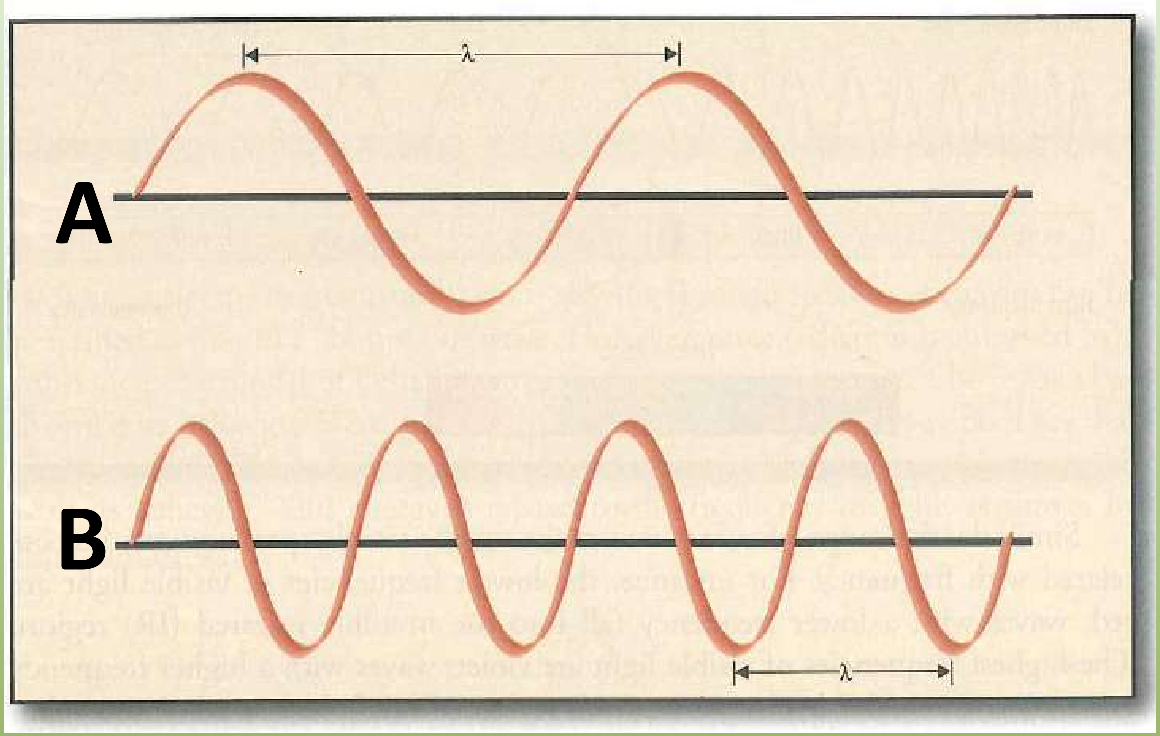
10/21/13

Part I: Light Behavior

- to understand why materials absorb light, one must first comprehend the nature of light
- two simple models explain light's behavior:
    - the first model describes light as a **continuous wave**
    - the second depicts it as a **stream of discrete energy particles**
- together, these two very different descriptions explain all of the observed properties of light, but by itself, no one model can explain all the facets of the behavior of light

Light as a Wave

- the wave concept depicts light as having an up-and-down motion of a continuous wave
    - using the wavelength and frequency definitions you wrote above, answer these questions:



1. Which wave has a longer wavelength? A B
2. Which wave has a higher frequency? A B
3. Assuming the picture represents 1 sec of time, how many cycles per second (Hz) are represented by wave A? ___2___
4. How many Hz are represented by wave B? ___4___
5. The frequency of wave B is (half, twice, quadruple) the frequency of wave A.

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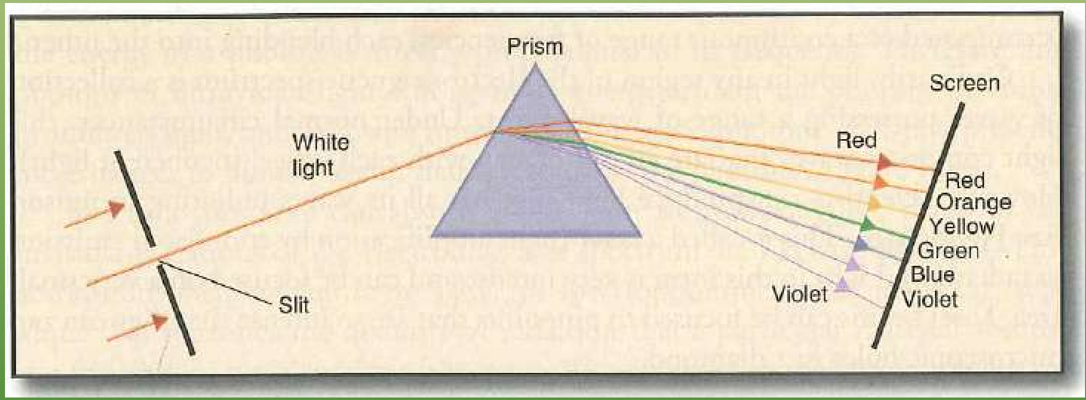
  - **dispersion** = the process of separating light into its component colors
- the speed of light in a vacuum is a universal constant at 300 million meters per second and is designated by the symbol *c*. (3×10^8 m/s)



- each color component of light, on passing through glass, is slowed to a speed slightly different from those of the others, causing each component to bend at a different angle as it emerges from the prism

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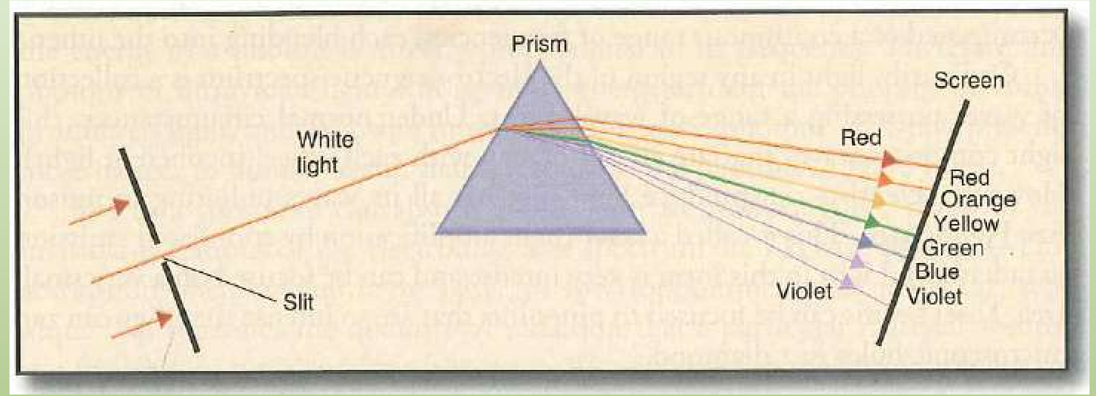

    - **refraction** = the bending of a light wave caused by a change in its velocity (speed)
- the observation that a substance has a color is also consistent with this description of white light—for example:
    - when light passes through a red glass, the glass absorbs all the component colors of light except red, which passes through or is transmitted by the glass

- when light passes through a red glass, the glass absorbs all the component colors of light except red, which passes through or is transmitted by the glass
- likewise, one can determine the color of an opaque object by observing its ability to absorb some of the component colors of light while reflecting others back to the eye
- color is thus a visual indication that objects absorb certain portions of visible light and transmit or reflect others
- scientists have long recognized this phenomenon and have learned to characterize different chemical substances by the type and quantity of light they absorb

SELF-CHECK QUESTION!

The bending of a light wave caused by a change in its velocity is known as refraction *.*

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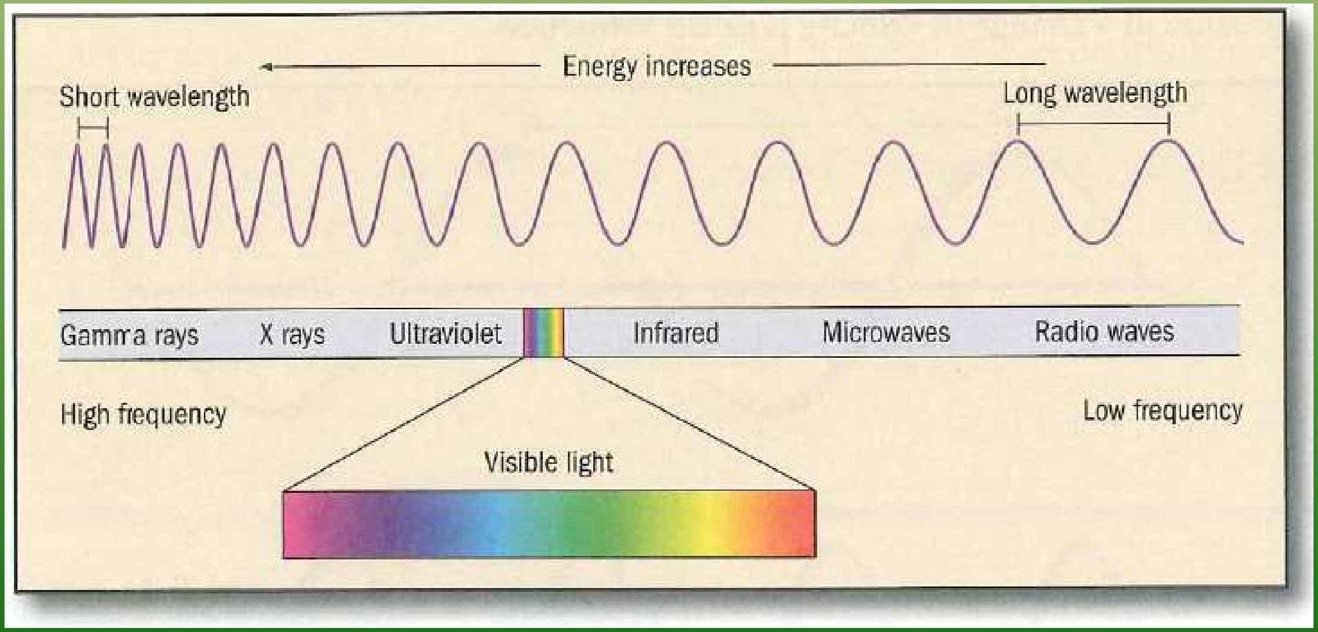
The Electromagnetic Spectrum

- visible light is only a small part of a large family of radiation waves known as the electromagnetic spectrum
  - **electromagnetic spectrum** = the entire range of EM radiation (from the most energetic cosmic rays to the least energetic radio waves)



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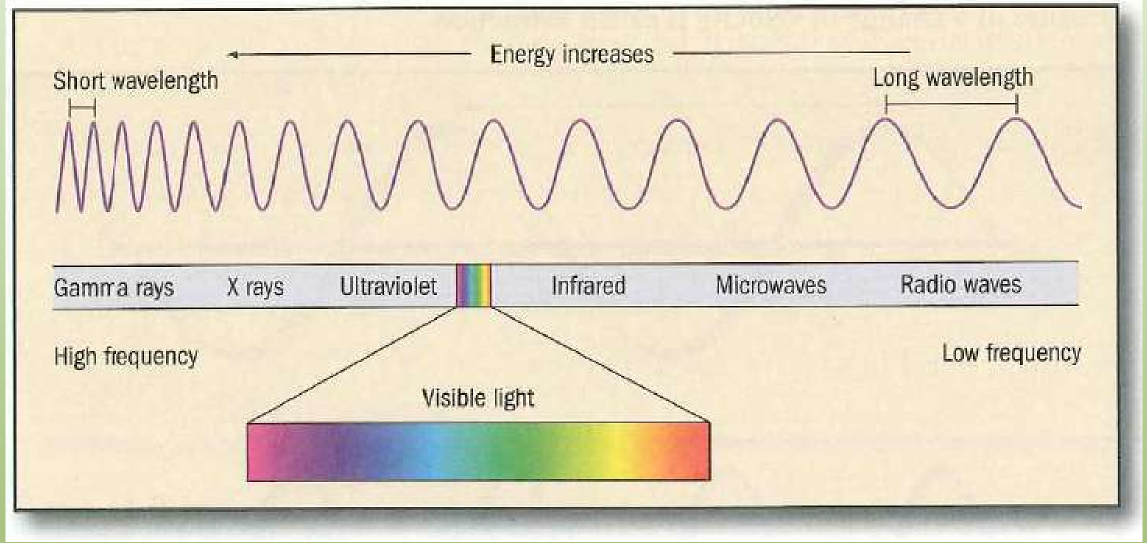
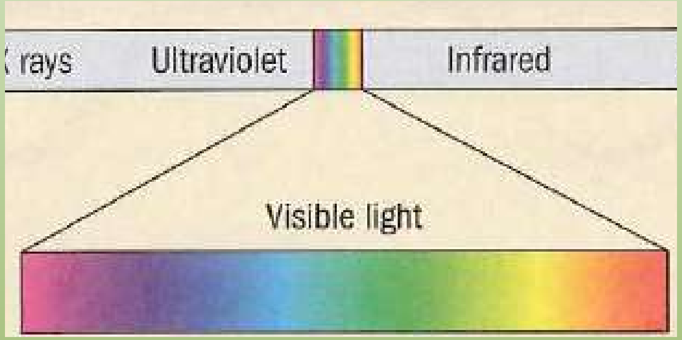


- all electromagnetic waves travel at the speed of light (c) and are distinguishable from one another only by their different wavelengths or frequencies
  - therefore the only property that distinguishes X-rays from radio waves is the different frequencies the two types of waves possess
  - similarly, the range of colors that make up the visible spectrum can be correlated with frequency—for instance:

- similarly, the range of colors that make up the visible spectrum can be correlated with frequency—for instance:
  - the lowest frequencies of visible light are red (waves with a lower frequency fall into the invisible infrared (IR) region)
  - the highest frequencies of visible light are violet (waves with a higher frequency extend into the invisible ultraviolet (UV) region)



- no definite boundaries exist between any colors or regions of the electromagnetic spectrum; instead, each region is composed of a continuous range of frequencies, each blending into the other

Light as a Particle

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Light as a Particle

- as long as electromagnetic radiation is moving through space, its behavior can be described as that of a continuous wave
- however, once radiation is absorbed by a substance, the model of light as a stream of discrete particles must be invoked to best describe its behavior
  - light can be depicted as consisting of energy particles that are known as **photons**
  - **photon** = a discrete particle of EM light radiation
    - each photon has a definite amount of energy associated with its behavior
    - energy of a photon is directly proportional to its frequency
- therefore, the photons of ultraviolet light will be more energetic than the photons of visible or infrared light, and exposure to the more energetic photons of X-rays presents more danger to human health than exposure to the photons of radio waves

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- **spectrophotometry** (an important analytical technique in chemical identification) measures the quantity of radiation that a particular material absorbs as a function of wavelength or frequency (MUCH more on this later)

SELF-CHECK QUESTION!

True or False? EM radiation, once absorbed into a substance, is best described as a ~~wave.~~

False (particle)

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Refractive Index

- reminder: the bending of a light wave because of a change in velocity is called **refraction**
- the phenomenon of refraction is apparent when we view an object that is immersed in a transparent medium (like water in a swimming pool):

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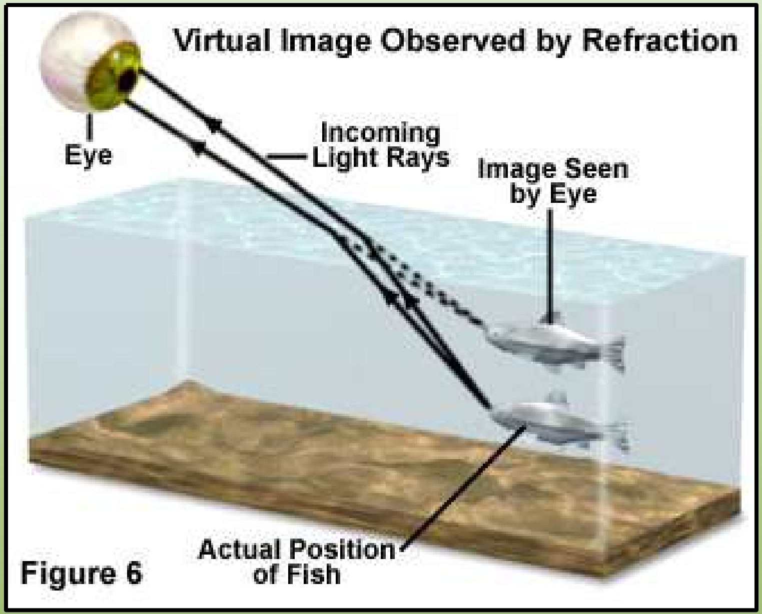
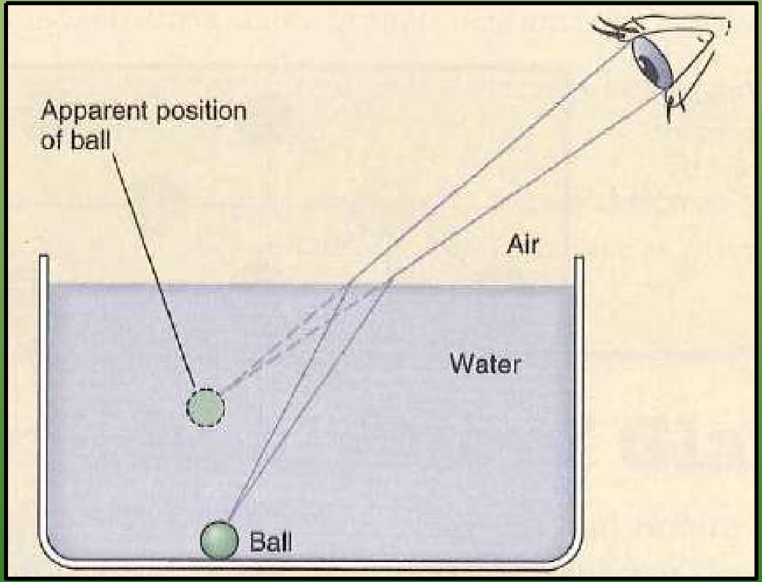
- reminder: the bending of a light wave because of a change in velocity is called **refraction**
- the phenomenon of refraction is apparent when we view an object that is immersed in a transparent medium (like water in a swimming pool):
  - because we are accustomed to thinking that light travels in a straight line, we often forget to take refraction into account
  - suppose a ball is observed at bottom of a pool of water—light rays reflected from ball travel through the water and into the air to reach the eye





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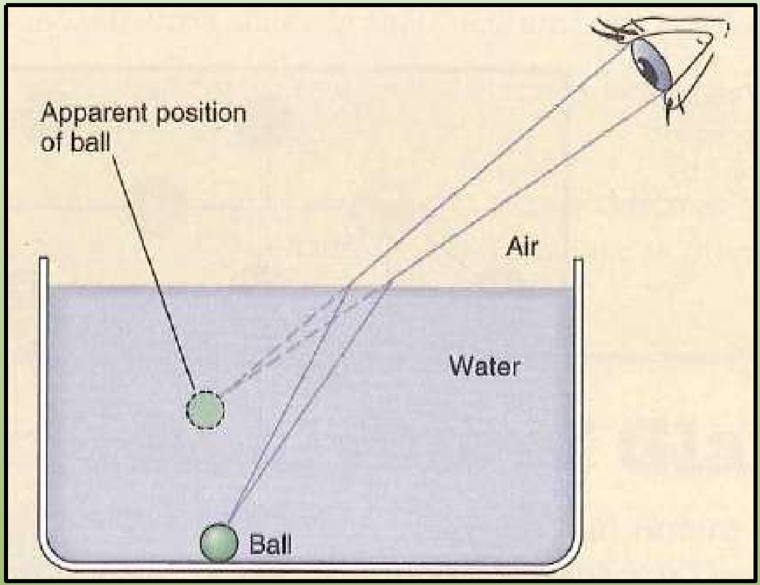

- suppose a ball is observed at bottom of a pool of water—light rays reflected from ball travel through the water and into the air to reach the eye
- as the rays leave the water and enter the air, their velocity suddenly increases, causing them to be refracted
- however, because of our assumption that light travels in a straight line, our eyes deceive us and make us think we see an object lying at a higher point than is actually the case

- **refractive index** = ratio of the velocity of light in a vacuum to that in any medium

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  - for example, at 25°C the refractive index of water is 1.333
  - this means that light travels 1.333 times as fast in a vacuum as it does in water at 25°C

$$\textbf{Refractive index} = \frac{\text{velocity of light in vacuum}}{\text{velocity of light in medium}}$$

- like density, the refractive index is an intensive physical property of matter and helps characterize a substance
  - procedures used to determine a substance's refractive index must be performed under controlled temp./lighting conditions, because the refractive index of a substance varies with its temp. and the wavelength of light passing through it
  - all refractive indices are determined at a standard wavelength, usually 589.3 nanometers (this is the predominant wavelength emitted by sodium light and is commonly known as the sodium D light, like a street lamp)


oil
CORNING

- this observation, as we will see, offers the forensic scientist a simple method for comparing the refractive indices of transparent solids (more on this later)
- normally, we expect a solid or a liquid to exhibit only one refractive index value for each wavelength of light, but many crystalline solids have two refractive indices whose values depend in part on the direction in which the light enters the crystal with respect to the crystal axis
  - **crystalline solid** = solids with a definite geometric form because of the orderly arrangement of its atoms; usually has 2 indexes of refraction (salt, minerals)
    - **birefringence** = diff. in the 2 indexes of refraction exhibited by most crystals
  - **amorphous solid** = solids with an indefinite form because of a random/disordered arrangement of its atoms; usually has 1 index of refraction (glass)

SELF-CHECK QUESTIONS!

What color is sodium D light?

orange-yellow

Refractive index is an ___intensive___ physical property.

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Part II: Composition of Glass

- glass is a hard, brittle, amorphous substance composed of sand (silicon oxides) mixed with various metal oxides

cullet = recycled glass

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- glass is a hard, brittle, amorphous substance composed of sand (silicon oxides) mixed with various metal oxides
  - when sand is mixed with other metal oxides, melted at high temperatures, and then cooled to a rigid condition without crystallization, the product is glass
  - soda (sodium carbonate) is normally added to the sand to lower its melting point and make it easier to work with
  - another necessary ingredient is lime (calcium oxide), needed to prevent the "soda lime" glass from dissolving in water
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- the forensic scientist is often asked to analyze soda-lime glass, which is used for manufacturing most window and bottle glass
- usually the molten glass is cooled on a bed of molten tin, producing a flat glass typically used for windows (this type of glass is called *float glass*).

- a wide variety of special glasses can be made by substituting in whole or in part other metal oxides for the silica, sodium, and calcium oxides
    - automobile headlights and heat-resistant glass, such as Pyrex, are manufactured by adding boron oxide to the mix (these glasses are therefore known as *borosilicates*)

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- **<u>tempered glass</u>** = glass made stronger than ordinary window glass by introducing stress through rapid heating and cooling of the glass surfaces
  - when tempered glass breaks, it does not shatter but rather fragments or “dices” into small squares with splintering

- when tempered glass breaks, it does not shatter but rather fragments or “dices” into small squares with little splintering
- because of this safety feature, tempered glass is used in side and rear windows of cars.

- **<u>laminated glass</u>** = glass made by sandwiching one of plastic between pieces of ordinary glass
  - the windshields of cars constructed from glass

SELF-CHECK QUESTIONS!

Name the 4 components of glass:

sand (silicon oxides)

various metal oxides

soda (sodium carbonate)

lime (calcium oxide)

Regular house windows are made with _________ glass.

float

- **laminated glass** = glass made by sandwiching one layer of plastic between two pieces of ordinary window glass
  - the windshields of cars are constructed from laminated glass

Part III: Comparing Glass Fragments

- glass possesses its greatest evidential value when it can be individualized to one source—however this can only be done when the suspect and crime-scene fragments are assembled and physically fitted together
  - the possibility that two pieces of glass originating from different sources will fit together exactly is so unlikely as to exclude all other sources from practical consideration

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- unfortunately, most glass evidence is either too fragmentary or too minute to permit a comparison of this type—however:
  - trace elements present in glass can narrow the origin of a glass specimen
  - the physical properties of density and refractive index are most widely used for characterizing glass particles (these properties are class characteristics, which cannot provide the sole criteria for individualizing glass to a common source)

SELF-CHECK QUESTION!

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